INTENSIFICATION OF A TROPICAL STORM AT HIGHER LATITUDE

The Case of September 14–15, 1904

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ABSTRACT

The tropical Low of September 14–15, 1904, is selected as a case for the study of a weak tropical Low intensifying as it moves to higher latitudes. By the use of barograms, thermograms, and autographic wind records, the storm track is reconstructed and hourly surface maps are drawn. The barograms, thermograms, and wind records are combined on single charts for individual stations showing that the increase in winds is associated with the inflow of cold air. The central pressure of the Low is determined and found to decrease as the Low moves northward. Filling of the Low begins after it moves north of 39.5° N.

1. INTRODUCTION

The relatively weak tropical cyclone that moved inland over eastern South Carolina early on the morning of September 14, 1904, was selected for study as an outstanding example of a weakened tropical storm which later intensified at a higher latitude. As the storm first moved inland the maximum 10-minute-average winds observed were about 40 m. p. h. Moving in a northeasterly direction, the storm crossed North Carolina, Virginia, Delaware, and New Jersey, and passed just off the coast of Rhode Island and Massachusetts. The 10-minute-average wind increased to 72 m. p. h. at Delaware Breakwater, Del. (with a reported 1-minute-average wind of 100 m. p. h.) shortly after the storm center passed. Although the damage was light to moderate in the Carolinas and Virginia, heavy losses were suffered in crops, buildings, and shipping from Delaware and New Jersey to Massachusetts. The reported loss to shipping was estimated to be $1,000,000 and the loss on land was estimated at $2,000,000. There were 14 lives lost. These figures are taken from newspaper reports of the time.

2. SOURCE OF DATA

Triple-register records and barograph and thermograph traces were the basic source of weather information. Monthly weather records (W. B. Form 1001) and original weather maps of the Weather Bureau were also used. Ten-minute-average windspeeds were extracted from the triple-register records and speed graphs were drawn. Wind direction graphs were also made from the triple-register records. The station pressure was read from the barograph trace and reduced to sea level. The original monthly weather records (W. B. Form 1001) were used to obtain the sea level correction; at stations where Form 1001 was not available but the barograph record was, the original weather maps of the Weather Bureau were used to obtain the sea level pressure correction.

3. METHODS OF APPROACH

The first step in the storm study was to determine, as accurately as possible, the hourly positions of the storm. The track of the storm (fig. 1) was drawn from just off the coast of South Carolina to just off the coast of Massachusetts.

Various methods were used to determine the storm track. The time of lowest pressure at a station was used

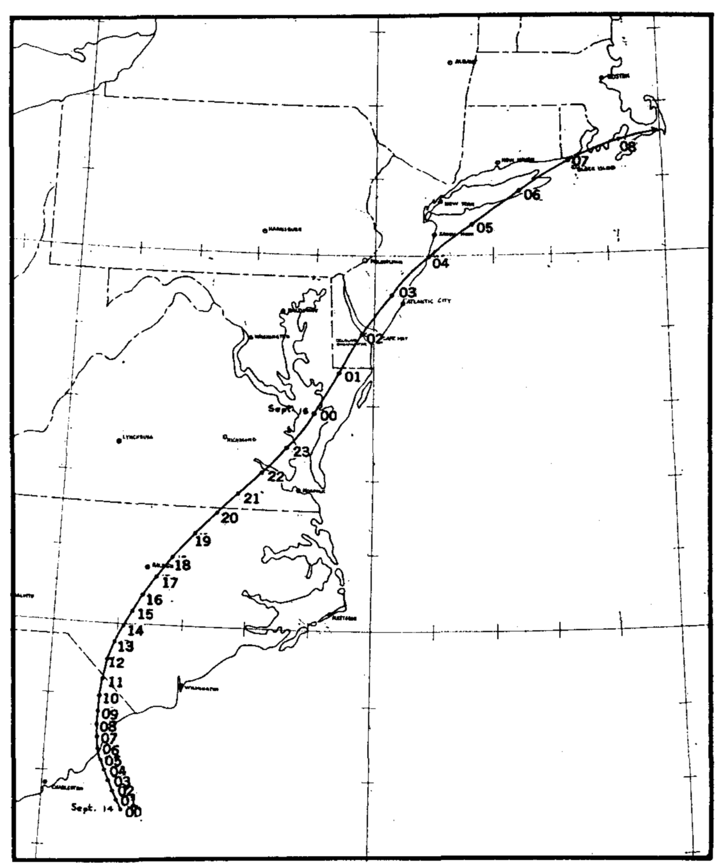

FIGURE 1.—Track of the tropical Low of September 14–15, 1904.

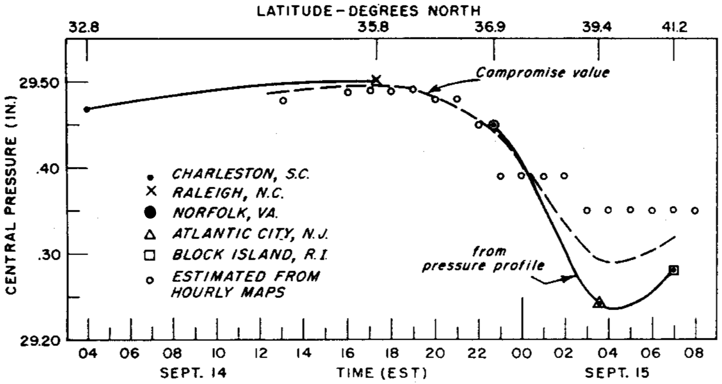

FIGURE 2.—Central pressure of the storm.

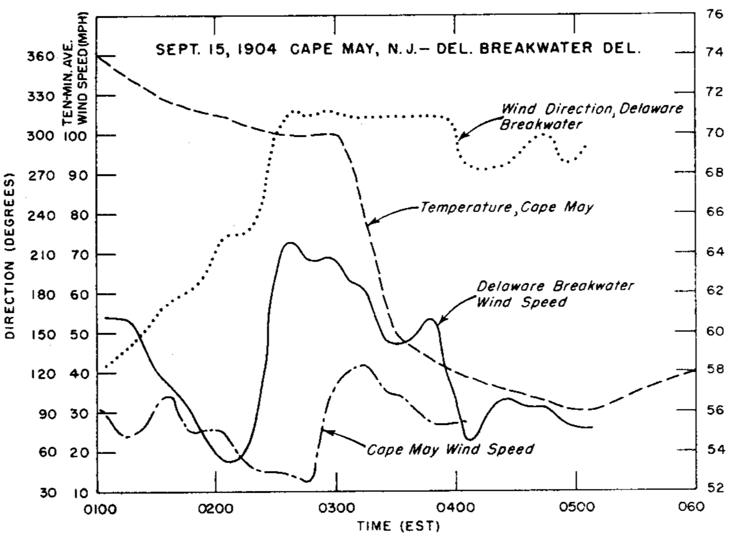

FIGURE 3.—Curves of wind direction and speed at Delaware Breakwater, Del., and the temperature record at Cape May, N. J. (roughly 10 miles east) during the passage of the storm, September 15, 1904.

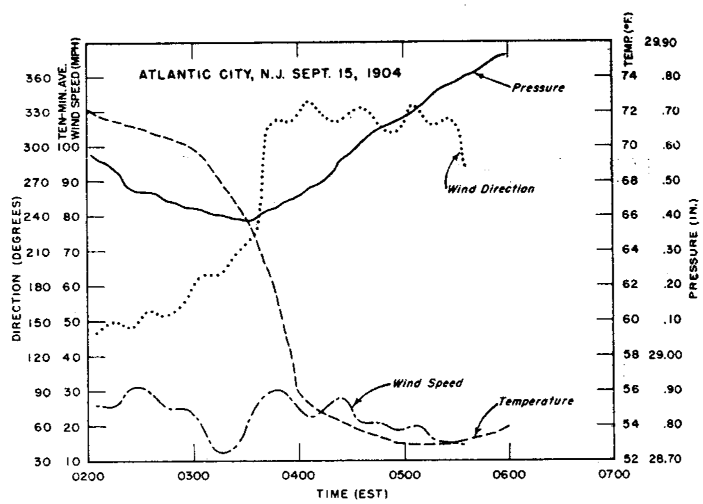

FIGURE 4.—Pressure, temperature, and wind records, Atlantic City, N. J., September 15, 1904.

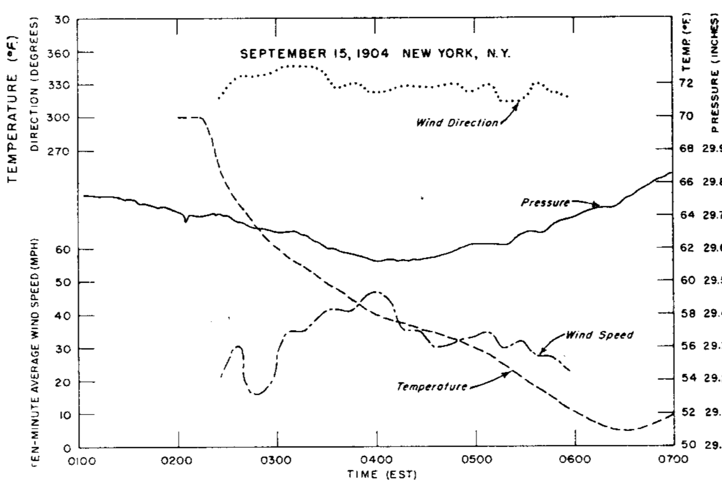

FIGURE 5.—Pressure, temperature, and wind records, New York, N. Y., September 15, 1904.

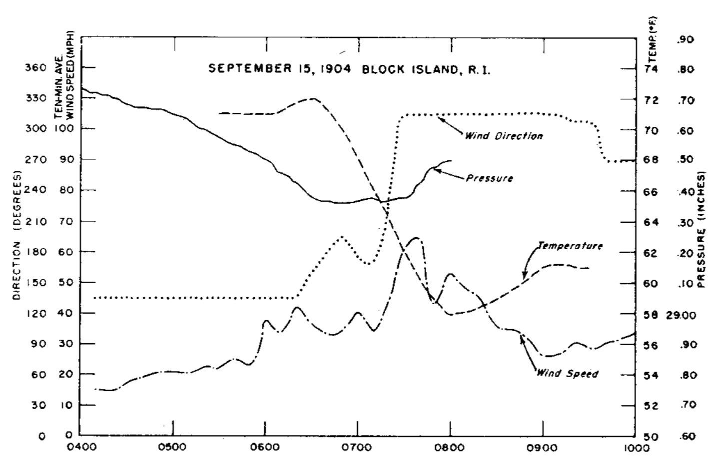

FIGURE 6.—Pressure, temperature, and wind records at Block Island, R. I., September 15, 1904.

to indicate the time the storm was nearest the station. To determine on which side of the station the storm passed, the wind direction was used. The rapidity with which the wind changed direction was used as a measure of the distance of the storm from the station. Barograms of two or more nearby stations were drawn on one chart and the point of intersection of two barograms was used as an indication of the time the storm was an equal distance from the two stations.

After a preliminary track had been constructed using this method, adjustments were made by getting agreement between the position of the storm center on the hourly weather maps and on this preliminary track. Adjustments of the track were also made after preliminary pressure profiles (discussed below) were constructed. In some instances several pressure profiles were made using a different position of a section of the track in each in an effort to find the most reasonable profile.

These methods are very well suited to finding the track of a hurricane which has a well-defined circulation around

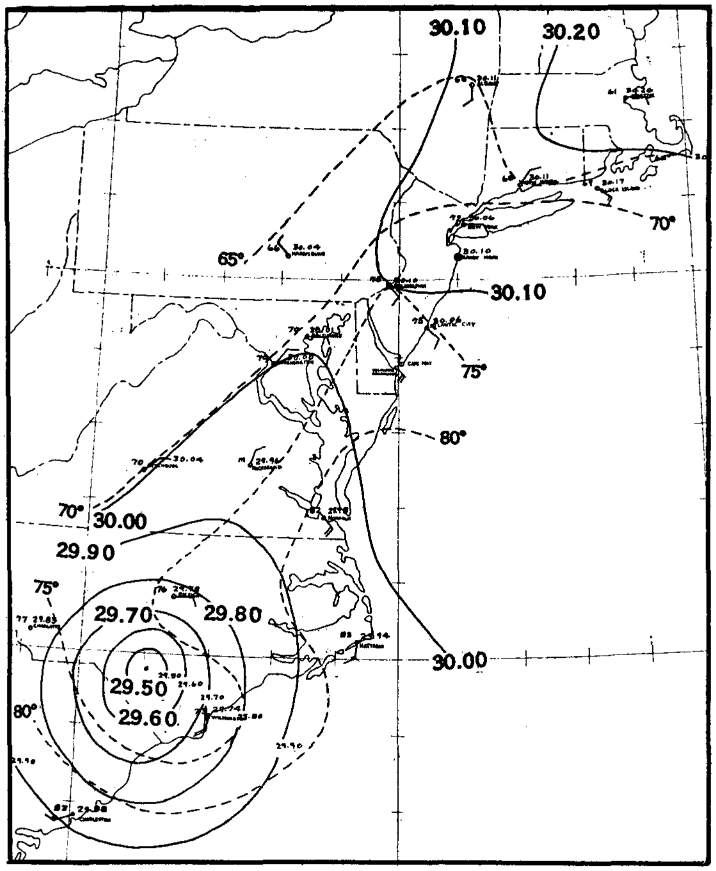

Figure 7.—Surface map, 1300 EST, September 14, 1904.

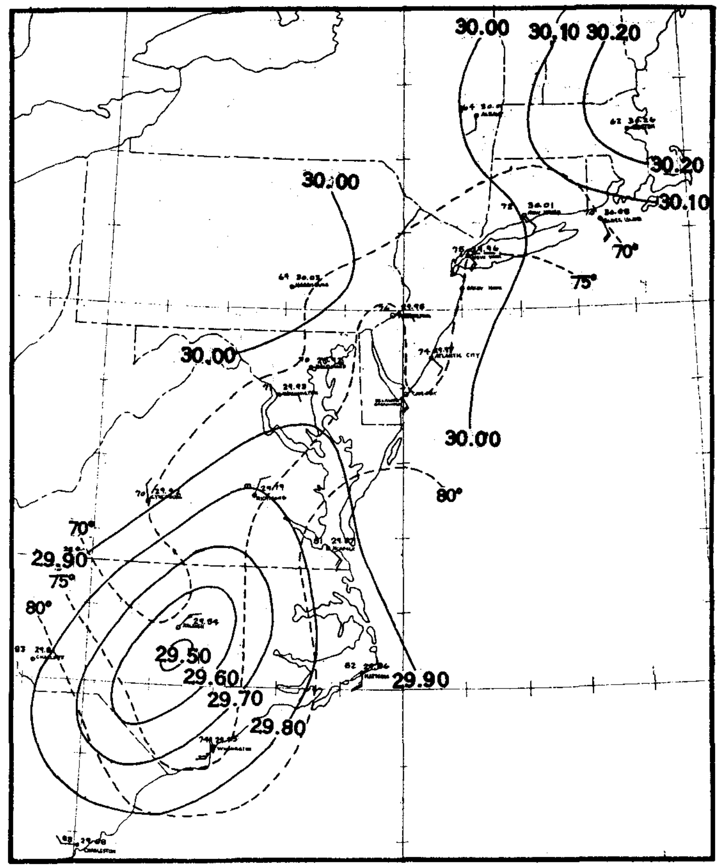

Figure 8.—Surface map, 1600 EST, September 14, 1904.

a circular pressure pattern. Since the storm in this study had a circulation that was elongated, the different methods did not always yield the same result. Because of this, in some portions of the track a compromise position was used as the best fit of the track to the weather data.

Pressure profiles (pressure plotted against distance from pressure center) were drawn using hourly pressures from barograms and the distance of the station from the pressure center of the storm at the same time as the pressure reading. A number of stations were used to determine the pressure profile for a given time.

The central pressure p_0 was computed by using the formula [1, 2]

$$\frac{p-p_0}{p_n-p_0}=e^{-R/r}$$

where p_n is the pressure at periphery of storm, R radius of maximum winds, and p pressure at any distance r from storm center. Three equations were used by substituting three different sets of values of p and r obtained from "observed" pressure profiles to solve for the three unknowns, p_0, p_n, and R. This formula was developed for hurricanes in which the pressure field is nearly symmetrical about a point and filling or deepening is negligible over a period of several hours. Although the pressure pattern of the storm in this study was elongated, the calculated value of p_0 is considered reasonable. The value of p_n is not considered very definite. The value of R is not as reliable as the value of p_0 since a small variation in the pressure profile may make a large difference in the value of R.

Hourly surface maps were constructed from thermograms, barograms, and triple-register data. The position of the cold front was determined principally from the thermograph records. The hourly maps were used to help in determining whether the storm was deepening and whether cold air was moving into it, as well as for establishing the storm track. The central pressure was estimated from each hourly map.

The relation of over-water to over-land wind was obtained from [2]. This relationship was used to compare the high wind speed at Delaware Breakwater which had an over-water trajectory with the lower reading across Delaware Bay at Cape May which had an over-land trajectory. Adjustment for anemometer height was also used to compare the two wind observations using the method discussed in [2]. The anemometer was 17 feet higher at Delaware Breakwater than at Cape May.

4. RESULTS

The central pressure of the storm decreased as the storm moved north of latitude 36° and then increased after the storm moved north of latitude 39.5°. This is indicated in figure 2, which shows the calculated central

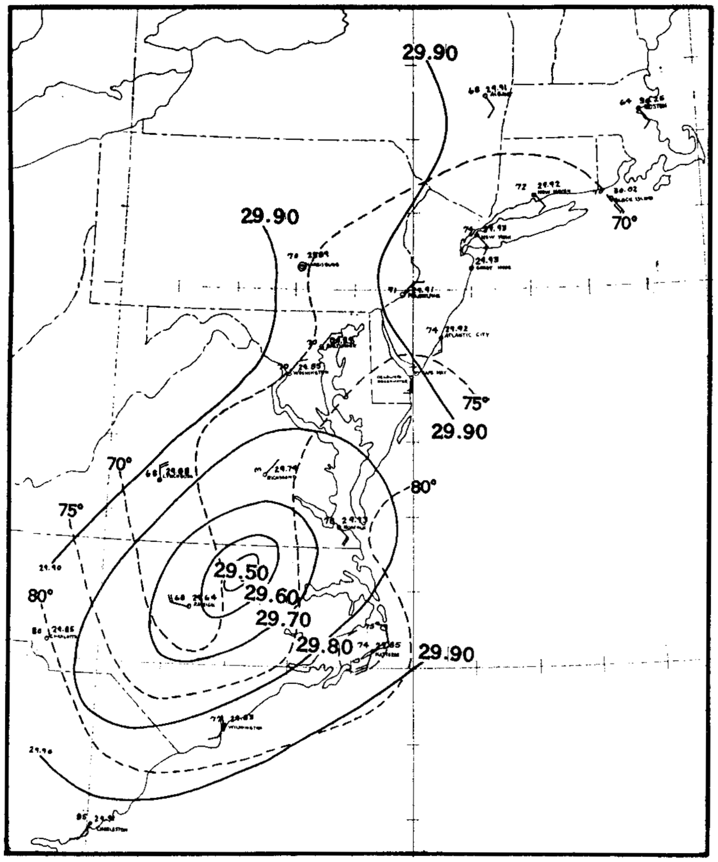

FIGURE 9.—Surface map, 1900 EST, September 14, 1904.

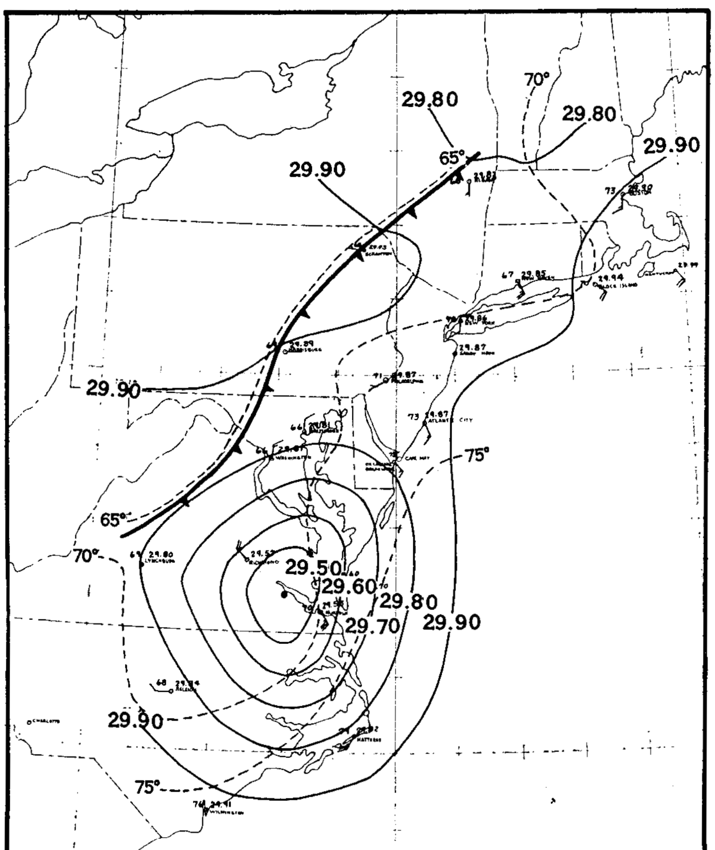

FIGURE 10.—Surface map, 2200 EST, September 14, 1904.

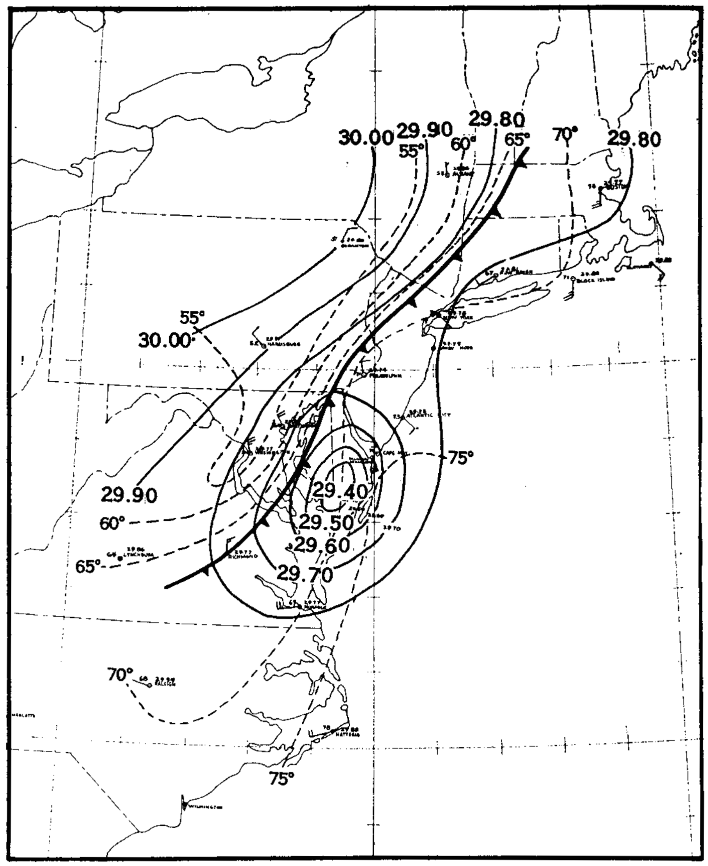

FIGURE 11.—Surface map, 0100 EST, September 15, 1904.

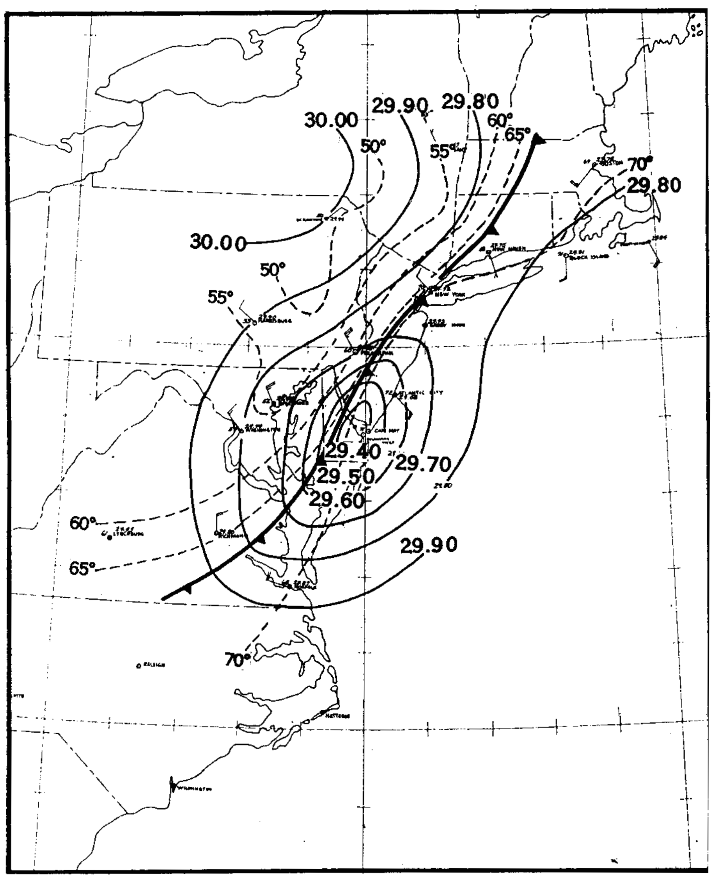

FIGURE 12.—Surface map, 0200 EST, September 15, 1904.

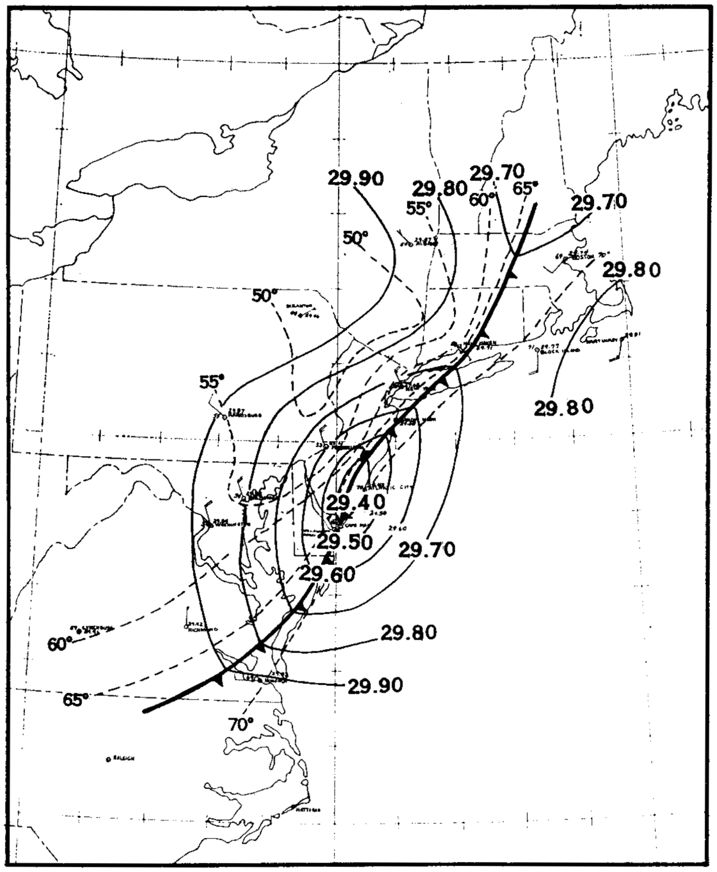

Figure 13.—Surface map, 0300 EST, September 15, 1904.

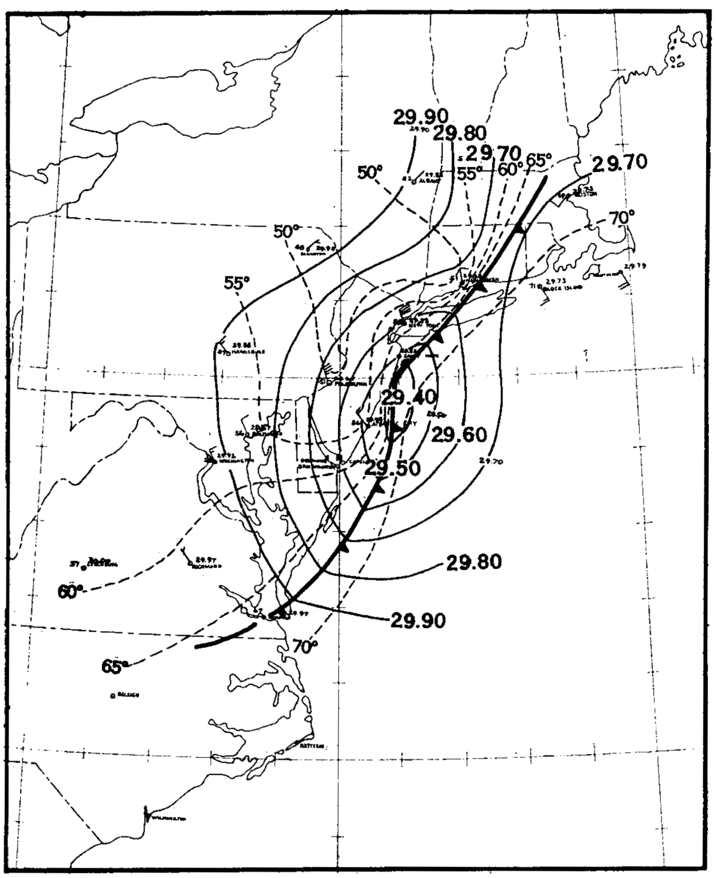

Figure 14.—Surface map, 0400 EST, September 15, 1904.

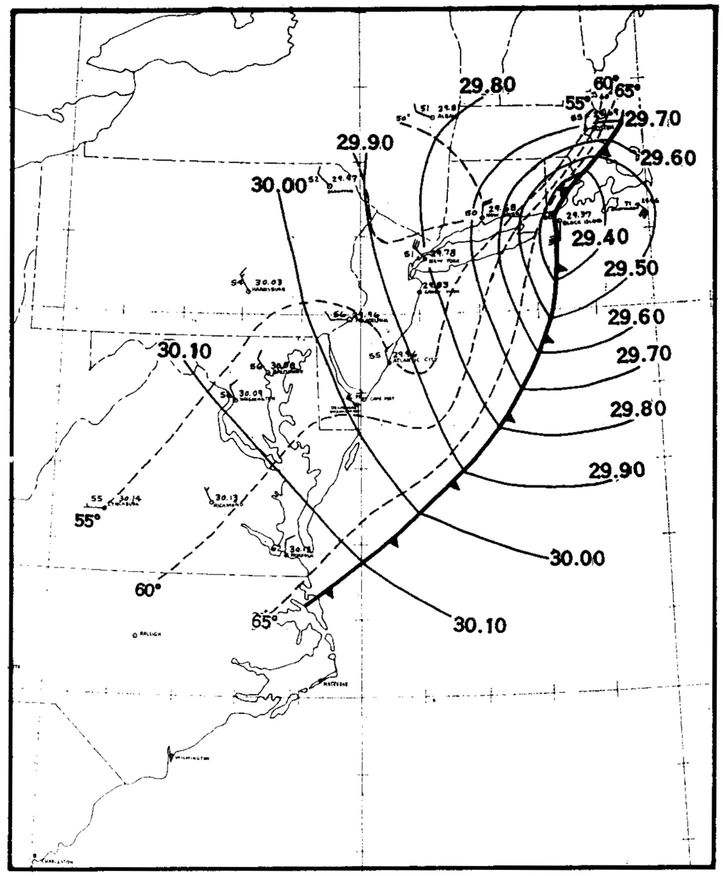

Figure 15.—Surface map, 0700 EST, September 15, 1904.

pressure, as well as the estimated central pressure from the hourly maps, and a compromise value for the various times and latitudes.

Cold air moved into the storm as the storm moved northward. This is shown in figures 3–6 which show the barogram and wind direction and speed curves along with the thermogram. Because thermograph and barograph records were not available for Delaware Breakwater, the thermograph from Cape May, N. J., was used with the Delaware Breakwater wind record as shown in figure 3. In this figure, the peak wind shortly precedes the sudden drop in temperature. Delaware Breakwater is roughly 10 miles west of Cape May, which accounts for this difference. Figures 4–6 show that the peak wind occurred after the drop in temperature and at about the time of lowest pressure. Of course, in the case of most cold frontal passages the drop in temperature occurs at about the time of lowest pressure. In this case, however, the lowest pressure was not caused by the frontal passage but by the low pressure of the storm center. This is shown by the surface maps in figures 7–15. The cold front did not move into the storm center and the trough associated with the storm center until 0300 EST of September 15, 1904. After that time the cold front moved along with the storm center.

There was no pronounced increase in wind speed at Atlantic City, N. J., when the cold front passed, as indicated in figure 4. No explanation of this lack of increase in wind speed at Atlantic City was found except that it might be due to the exposure of the anemometer.

The unusually high windspeed observation at Delaware Breakwater does not agree with observations from other near-by points such as Cape May, but after adjusting for anemometer height and over-water trajectory there is reasonable agreement between these two observations. Table 1 shows the wind correction for anemometer height and trajectory. The *Monthly Weather Review* and newspapers of September 1904 reported the maximum wind at Delaware Breakwater as 100 m. p. h. This wind speed was found to be the maximum 1-minute average obtained from the triple register without application of the anemometer correction. With a 4-cup anemometer correction applied this maximum wind speed becomes 76 m. p. h.

Maximum wind speeds in hurricanes prior to 1928 may be reported 20 to 25 percent high, because prior to that date no anemometer correction was applied to wind observations. It appears that many reports relating to the maximum winds of these earlier hurricanes also have not applied the anemometer correction.

TABLE 1.—*Wind correction for anemometer height and trajectory*

Station	Maximum wind (10-min.-avg.) (m. p. h.)	Anemometer height (ft.)	Trajectory	Correction (percent) (from [2])			Maximum windspeed adjusted to 51 ft. over land (10-min.-avg.) (m. p. h.)
				Anemometer height	Trajectory	Total	
Delaware Breakwater, Del.	76	68 above water.	Over water	−3	−28	−31	52
Cape May, N. J.	42	51 above ground.	Over land	0	0	0	42

5. CONCLUSIONS

1. The intensification of this storm was accompanied by inflow of cold air.
2. Unusually high winds may occur when a storm is moving over land in such a way that the wind has an over-water trajectory.
3. While most storms have the strongest winds in the forward right quadrant, this storm had the strongest winds in the rear left quadrant, associated with the inflow of cold air.
4. The strong winds were not caused by a squall since they persisted for about one hour at Delaware Breakwater; the wind remained in the west to northwest direction, and there was no pronounced temperature rise after the sudden drop.

ACKNOWLEDGMENTS

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REFERENCES

1. Robert W. Schloemer, "Analysis and Synthesis of Hurricane Wind Patterns Over Lake Okeechobee, Florida," *Hydrometeorological Report* No. 31, U. S. Weather Bureau, Washington, March 1954, 49 pp. (pp. 12–17).
2. Vance A. Myers, "Characteristics of United States Hurricanes Pertinent to Levee Design for Lake Okeechobee, Florida," *Hydrometeorological Report* No. 32, U. S. Weather Bureau, Washington, March 1954, 106 pp. (pp. 2, 14, 21).